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Attorney's Docket No. 01997-270001 / MIT 8554

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant	: Erik R. Thoen et al.	Art Unit	: 2881
Serial No.	: 09/542,061	Examiner	: J. Menefee
Filed	: April 3, 2000		
Title	: SEMICONDUCTOR ELEMENTS FOR STABILIZING LASER OUTPUT		

Commissioner for Patents
Washington, D.C. 20231

SECOND AFFIDAVIT OF ERIK R. THOEN UNDER 37 C.F.R. § 1.131

I, Erik R. Thoen, declare as follows:

1. I am the same Erik Thoen who executed the Affidavit of Erik R. Thoen Under Rule 37 C.F.R. sec. 1.131, executed October 2, 2001, and submitted with the Response dated October 4, 2001 ("my First Affidavit").

2. I have read the Office Action mailed December 20, 2001, and the U.S. Patent No. 6,252,892 B1 to Jiang et al. ("the Jiang patent"), cited by the Examiner in the Office Action. The Jiang patent was filed on September 8, 1998.

3. Our pending patent application includes two independent claims directed to producing non-linear increasing loss in a passive mode-locked laser system (claims 10, 26), and one independent claim directed to producing non-linear increasing loss in either a passively or actively mode-locked laser system (claim 1).

CERTIFICATE OF MAILING BY FIRST CLASS MAIL

I hereby certify under 37 CFR §1.8(a) that this correspondence is being deposited with the United States Postal Service as first class mail with sufficient postage on the date indicated below and is addressed to the Commissioner for Patents, Washington, D.C. 20231.

June 18, 2002
Date of Deposit

Maureen Christiano
Signature

MAUREEN CHRISTIANO
Typed or Printed Name of Person Signing Certificate

4. Before September 8, 1998, I conceived of the invention of independent claims 1, 10, and 26, and reduced an embodiment to practice.

a) Before September 8, 1998, co-inventors and I conceived a laser system with a pump, a gain medium producing radiation at an operative wavelength, and a reflector disposed along an optical path in the laser system's cavity, where the reflector includes layers of a first semiconductor material that act as a saturable absorber, and layers of a second semiconductor material that produces nonlinearly increasing loss to stabilize the mode-locked output of the laser system.

b) This conception was recorded in my lab notebook. In my notebook, I calculated that a Bragg mirror having a particular InGaAsP/InP structure and an AR coating, when placed along an optical path in a laser system producing radiation at an operative wavelength of 1540 nm, would produce non-linearly increasing TPA loss, in addition to saturable absorption. These pages from my lab notebook were attached as Exhibit A to my First Affidavit. (The date was redacted from the notebook pages attached as Exhibit A. I represent that this redacted date is earlier than September 8, 1998.)

c) Shortly after performing the above calculations, I measured the reflectivity of the InP InGaAsP Bragg reflector described in subparagraph (b) above using a Kerr-lens mode-locked laser system producing radiation at 1530 nm, with 150 fs pulses. The data showed saturable absorption and nonlinear increasing loss. A graph depicting this data was attached as Exhibit B to my First Affidavit. (I have redacted the date of the experiment from Exhibit B. I represent that this redacted date is earlier than September 8, 1998.)

d) I believe the laser system I used in the experiment described in subparagraph (c) meets all the elements of independent claim 1. The laser system in the experiment defined a cavity, and produced radiation at an operative wavelength. The system included a mode-locking element configured to mode-lock output of the laser (the Kerr-lens), and a semiconductor element (layer of InP) that produced nonlinear increasing loss at the operative wavelength sufficient to enhance stability of the mode-locked output.

e) I also believe my performance of the experiment described in subsection (c) meets all the elements of method claim 26, for the reasons discussed above in subparagraphs (c) and (d).

f) After performing the experiment of subparagraph (c), I tested this same reflector in a laser system that was not Kerr-lens mode-locked, to demonstrate that the saturable absorption produced by the reflector in the experiment of subparagraph (c) could mode-lock the laser's output. Attached to this Affidavit as Ex. 1 are my lab notebook pages showing the results of this experiment. The first four pages of Ex. 1 are my analysis of the raw data, and the last four are graphs showing the data. As demonstrated clearly by the last two graphs, this laser system is mode-locked by the saturable absorption layers in the reflector at the same operative wavelength that produces nonlinear increasing loss. (The dates in Ex. 1 have been redacted. I represent that these dates are prior to September 8, 1998.)

g) I believe that my experiment of subparagraph (f), in view of the data from the experiment of subparagraph (c), satisfies all the elements of claim 10. The experiment of subparagraph (d) included a pump, a gain medium that produced radiation at an operative wavelength, and a reflector disposed along an optical path in the laser system's cavity. The reflector included layers of a first semiconductor material (InGaAsP) that acted as a saturable absorber at the operative wavelength to mode-lock output of the laser, and one or more layers of a second semiconductor material (InP). As demonstrated by the data shown in experiment (c), the InP produces nonlinear increasing loss at the operative wavelength sufficient to enhance the stability of the mode-locked output.

5. I affirm, under penalty of perjury, that all statements made herein are true, to the best of my knowledge, information and belief.

Dated: 6/13/02

E R Th

Erik R. Thoen

Sat Abs

Redacted

· TPA Effects

Saturation measurements

various structures

range of lenses

simple modelling

mirror alone.

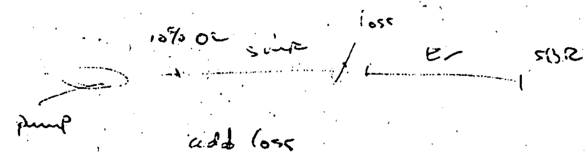
vary λ

ps vs fs ⇒ proof of mechanism.

NaCl vs APO

on stretching

Simple cavity



add loss

identical single pass gain

different cavity config

only diff Er fiber vs waveguide.

demonstrate pulses limited by TPA.

AC / spectrum.

disp shift vs SWF

soliton or no sol shaping.

Phase Measurements

explanation of dynamics

relate to SOAs.

introduce χ's

simple w/ large response.

Noncollinear measurement

expectations based on SOAs but really CW

associated theory paper

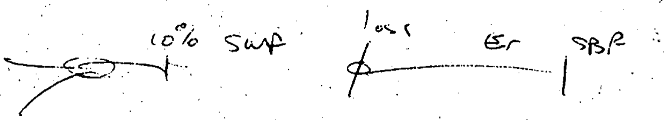
General dynamics

Done already

Need to relate to lasing characteristics

Proton bombardment changing time const

Absorber Design.



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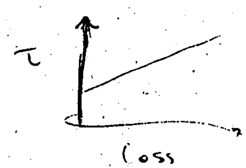

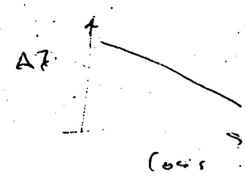

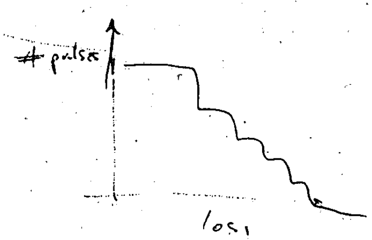

Investigate multiple pulsing

previously w/ power dependence

Saturable Absorber Dynamics

Varies pulse energy?

high loss cases for waveguide

investigate requirements

vary through Q switch

Q sw modelocked

cw modelocked:

illustrate continuous control of dynamics

lower y need lower loss attenuator

2. Is pumping the same as loss?

Modelocking risetime

In fiber?

in line dropper?

Now SBR IV A2   t = 20 cm

I	Pout
100	
200	
300	

The un[illegible]tion is λ w/ focus was the same as for the HR.

Here in the time domain I don't ~~[illegible]~~ observe QS or QSML

On the rf spectrum analyzer

The air cavity forms a FP ~~[illegible]~~ ~~[illegible]~~ filterin of the modes

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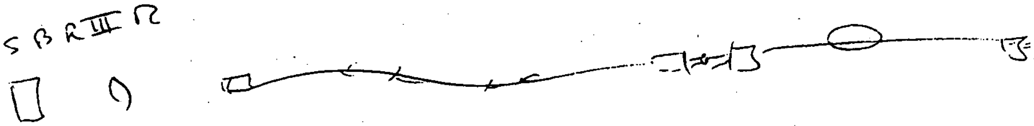
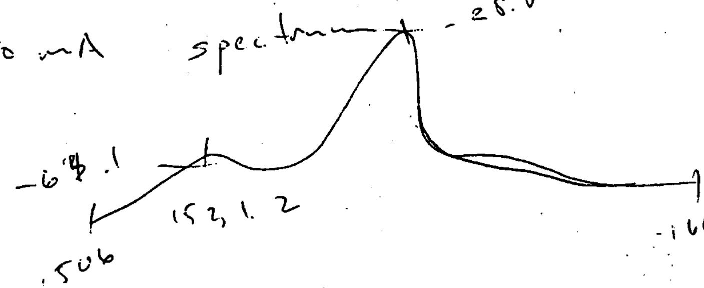
Changing to SBR III Resonant

SBR III R



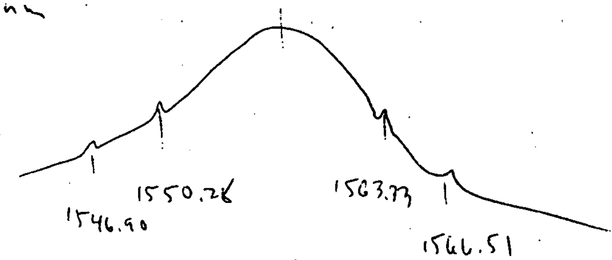
at 150 mA spectrum



Saved in 98073101.osa

Blow up (30 nm span)

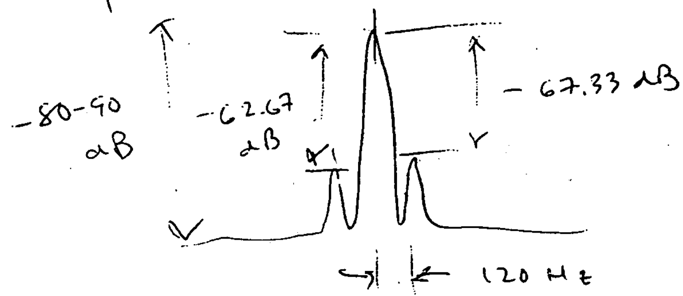
3dB 3.37 nm



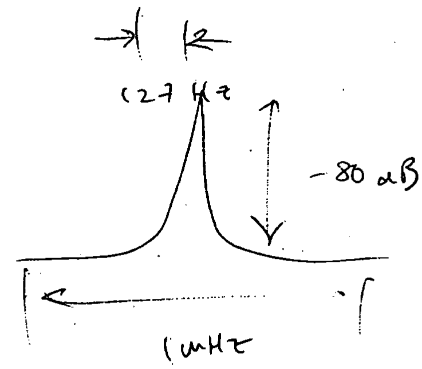
98073102.osa

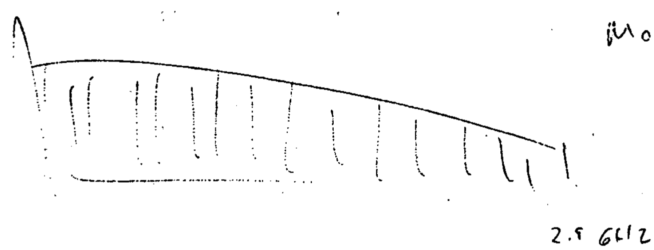
Redacted

Measuring the rep rate 42.234458 MHz



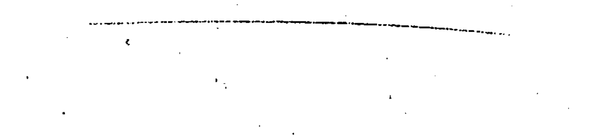
2 KHz span



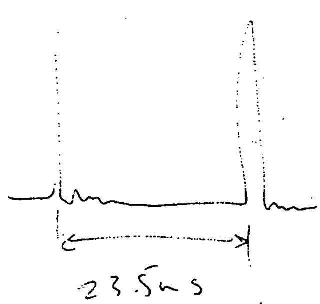


Modes locked to 2.9 GHz

Time domain:-



completely flat on a 1 ms time base



pulsewidth limited to detector BW

Redacted

QS

I	T_p
90	64 ms
100	55 ms
110	52 ms
120	46 ms
130	43 ms

CW modelocking

125.5 — 100
125 — 164

Very sensitive to backreflections
measurements taken w/ FC connector screwed in all the way.

QS

I	T_p
170	36 ms
180	34 ms
220	30 ms
250	~~27~~.5 ms
300	25 ms

$P_{in} T_{WDM} T_{OC} = P_{out}$

$P_{in} = \frac{P_{out}}{T_{WDM} T_{OC}} = \frac{P_{out}}{0.15}$

$= 6.3309 P_{out}$

CW

I	Pout	Calculated Intercavity Power	$E \left(\frac{mJ}{cm^2}\right)$
150 mA	0.49 mW	3.10 mW	73.91
140	0.43	2.72	64.85
130	0.38	2.41	57.46
100	0.55	3.48	82.97

all seem to make sense

Redacted

Calculating the pulsewidth assuming transform limited pulses.

$$\Delta\tau\,\Delta\nu = 0.3148 \qquad \text{sech}$$

$$\nu = \frac{c}{\lambda} \qquad \frac{\partial\nu}{\partial\lambda} = \frac{c}{\lambda^2} \qquad \Delta\nu = \frac{c}{\lambda^2}\Delta\lambda$$

$$\Rightarrow \Delta\tau = \frac{0.3148\,\lambda^2}{c\,\Delta\lambda}$$

$$\Delta\tau = \frac{0.3148\,(1556.84\times10^{-9}\,m)^2}{(3\times10^8\,m/s)(3.37\times10^{-9}\,m)} =$$

$$\Delta\tau = 754.7\text{ fs}$$

So at least it should be sub-picosecond.

Now let's try to obtain the other cavity parameters.

Estimate spot size OZ output $1.1\times10^{-3}\,m = d$

Gaussian focussed spot diameter. $f = 6.24\,mm = 6.24\times10^{-3}\,m$

$$a = \frac{4\lambda f}{\pi d} = \frac{4\,(1556.84\times10^{-9}\,m)(6.24\times10^{-3}\,\cancel{m})}{\pi\,(1.1\times10^{-3}\,\cancel{m})}$$

$$a = 1.1245\times10^{-5}\,m = 11.25\,\mu m \leftarrow$$ very close to the fiber modefield diameter

Now the energy density

$$E = \frac{P_{av}}{f}\,\frac{1}{\pi\left(\frac{a}{2}\right)^2} = \frac{P_{av}\left(\frac{mJ}{s}\right)}{(42.234\times10^{6}\,1/s)}\;\frac{1}{\pi\left(\frac{1.1245\times10^{-5}\,m}{2}\left(\frac{m}{100\,cm}\right)\right)^2}\left(\frac{1000\,\mu J}{mJ}\right)$$

$$= P_{av}(mW)\;2.3843\times10^{5}\;\left(\frac{\mu J}{m}\right)$$

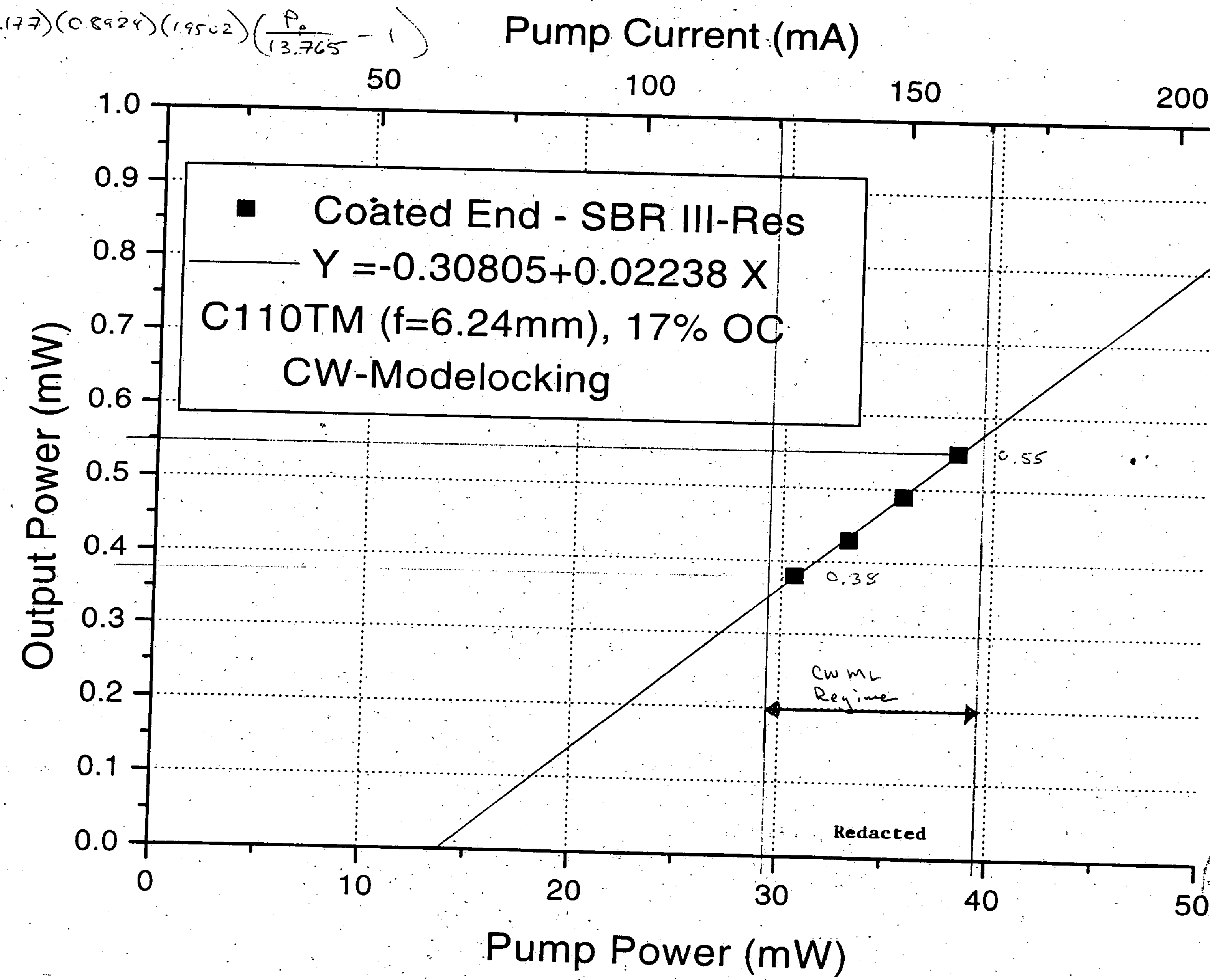
$$= P_{av}(mW)\;23.843\;\left(\frac{\mu J}{cm^2}\right)$$

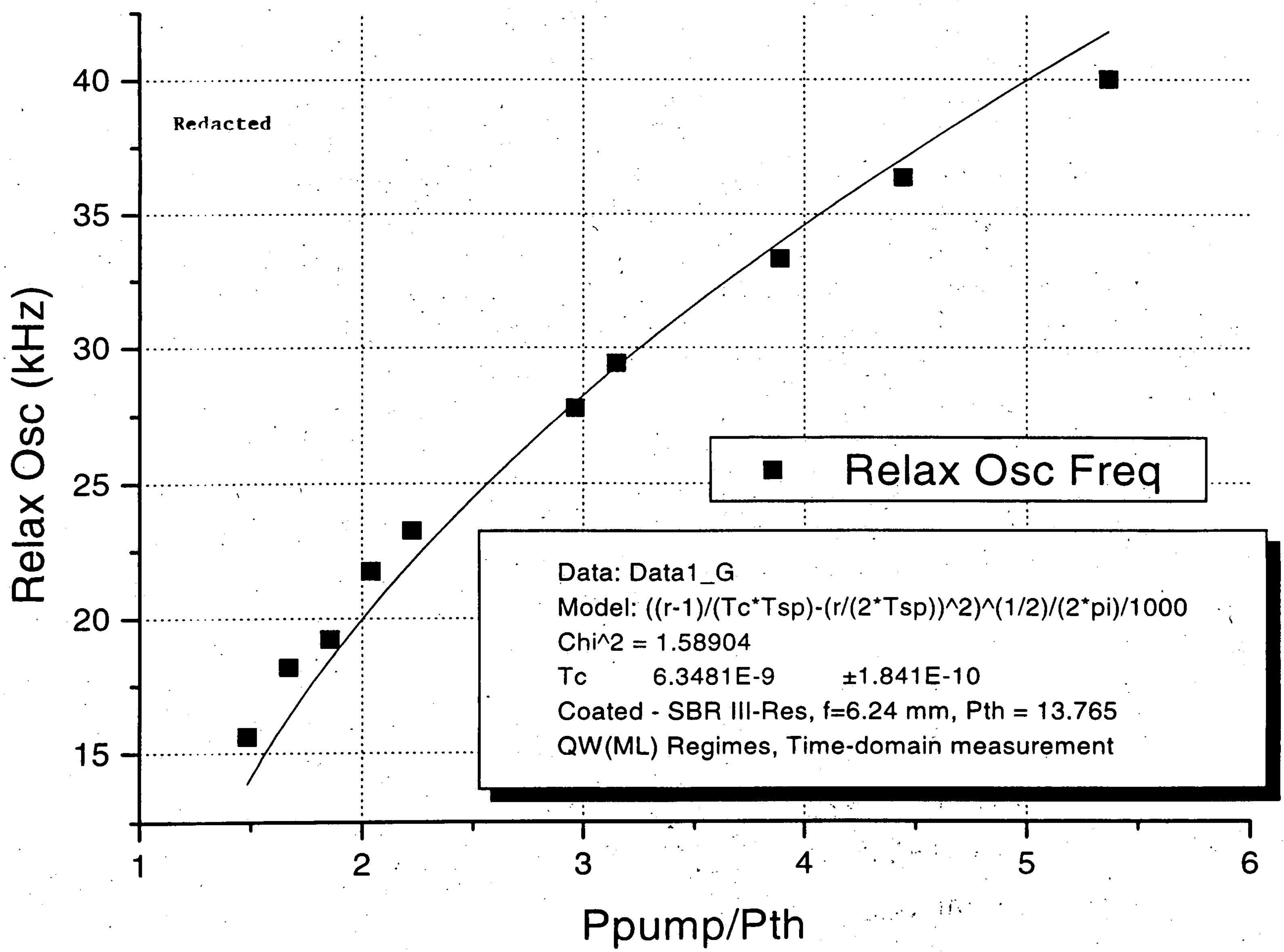
calculating on the previous page

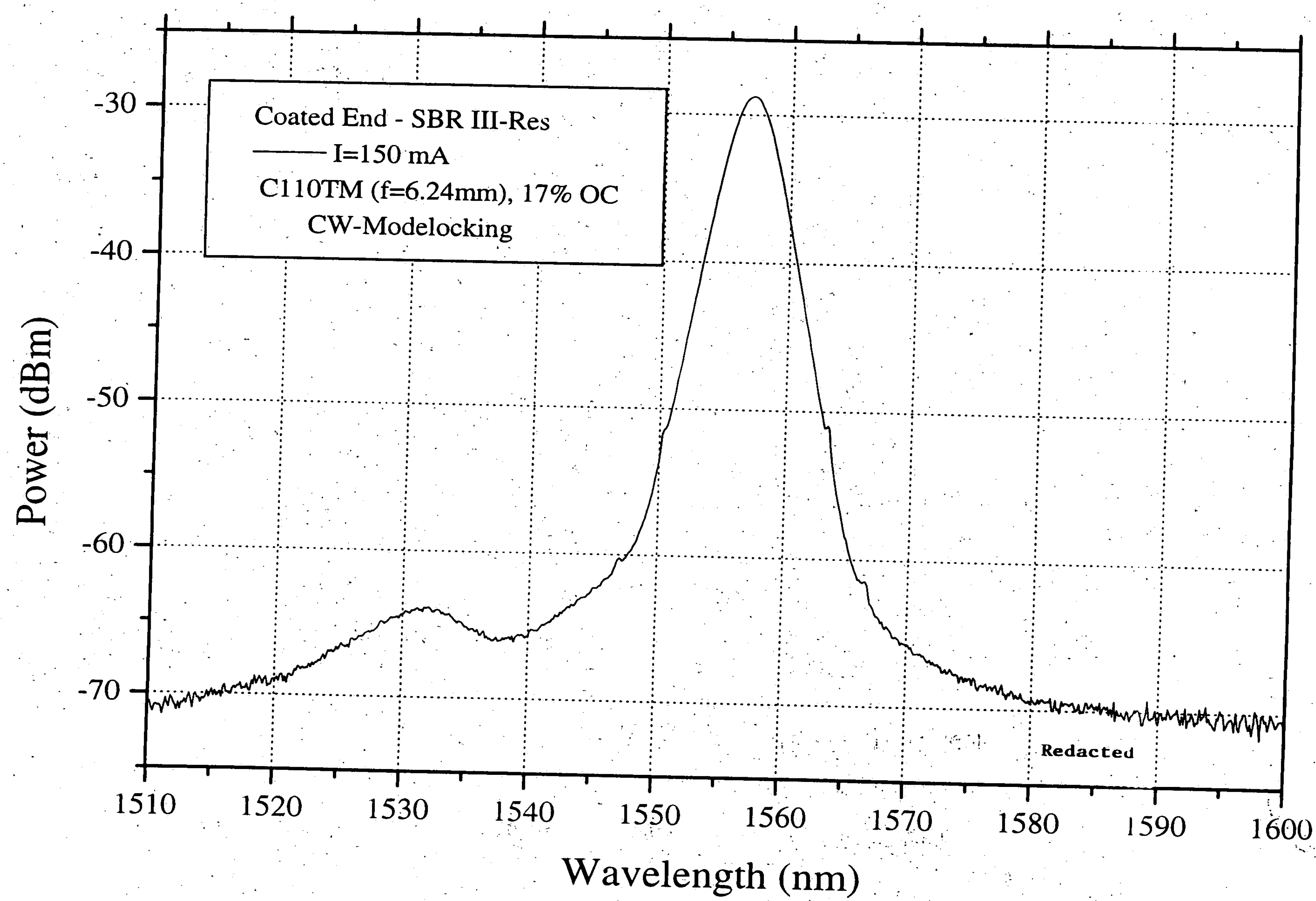
1

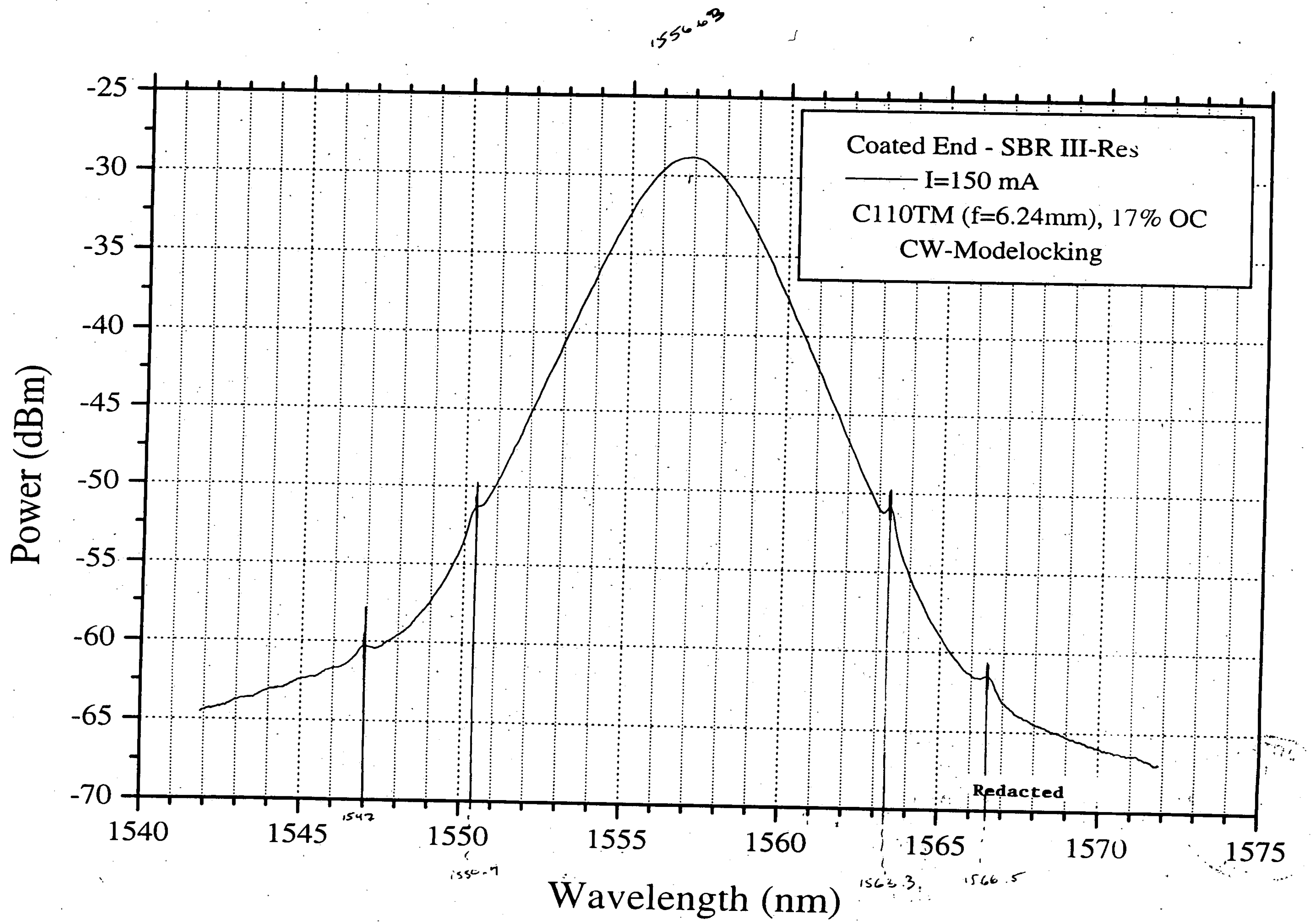
$P_{out} = T_{oc} T_{UAm} P_h \left(\frac{P}{P_{th}} - 1 \right)$

$= (0.177)(0.8924)(1.9502)\left(\frac{P_o}{13.765} - 1 \right)$




Relax Osc (kHz)
Ppump/Pth
Redacted
Relax Osc Freq
Data: Data1_G
Model: ((r-1)/(Tc*Tsp)-(r/(2*Tsp))^2)^(1/2)/(2*pi)/1000
Chi^2 = 1.58904
Tc 6.3481E-9 ±1.841E-10
Coated - SBR III-Res, f=6.24 mm, Pth = 13.765
QW(ML) Regimes, Time-domain measurement


Coated End - SBR III-Res
I=150 mA
C110TM (f=6.24mm), 17% OC
CW-Modelocking
Power (dBm)
-30
-40
-50
-60
-70
1510
1520
1530
1540
1550
1560
1570
1580
1590
1600
Wavelength (nm)
Redacted


Coated End - SBR III-Res
I=150 mA
C110TM (f=6.24mm), 17% OC
CW-Modelocking
Power (dBm)
Wavelength (nm)
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
1540
1545
1550
1555
1560
1565
1570
1575
Redacted
1547
1550.7
1563.3
1566.5
1556.8